

Prospective Outcomes of Young and Middle-Aged Adults With Medial Compartment Osteoarthritis Treated With a Proximal Tibial Opening Wedge Osteotomy

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Purpose: The purpose of this study was to conduct a prospective outcome analysis of proximal tibial opening wedge osteotomies performed in young and middle-aged patients (aged <55 years) for the treatment of symptomatic medial compartment osteoarthritis of the knee. **Methods:** A consecutive series of young and middle-aged adults who underwent proximal tibial opening wedge osteotomies for symptomatic medial compartment osteoarthritis and genu varus alignment were prospectively followed up. Patients were evaluated with preoperative and postoperative modified Cincinnati Knee Scores and International Knee Documentation Committee objective knee subscores for knee effusions and the single-leg hop. Calculations were made of the preoperative and postoperative long-leg radiographic mechanical weight-bearing axis, patellar height (Insall-Salvati index), and tibial slope. A separate cohort of asymptomatic patients was used to quantify tibial plateau anatomy to provide an objective description of the lower extremity mechanical axis. **Results:** There were 47 patients, with a mean age of 40.5 years, with a minimum of 2 years' follow-up, who formed this patient cohort. Modified Cincinnati Knee Scores improved significantly from 42.9 preoperatively to 65.1 at a mean of 3.6 years of follow-up. Radiographic analysis of a separate cohort showed the medial tibial eminence to be located at the 41% point along the tibial plateau from medial (0%) to lateral (100%). There was a significant improvement in malalignment: the mean mechanical axis passed through the tibial plateau at 23% of the distance along the proximal tibia preoperatively versus 54% postoperatively. The Insall-Salvati index decreased from 1.03 to 0.95 ($P < .05$), and posterior tibial slope increased from 9.4° to 11.7° ($P < .05$). Of the osteotomies, 3 (6%) were considered failures, defined by revision of the osteotomy or conversion to total knee arthroplasty. **Conclusions:** Performing proximal tibial opening wedge osteotomies to treat symptomatic medial compartment osteoarthritis in carefully selected patients leads to a significant improvement in subjective and objective clinical outcome scores with correction of malalignment at a mean of 3.6 years postoperatively. **Level of Evidence:** Level IV, therapeutic case series.

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Despite the expanding indications for knee arthroplasty,¹ it is advantageous to delay arthroplasty given the higher wear rate and likelihood of future complex revisions if the primary surgery is performed in patients at a young age.² Proximal tibial osteotomy, a joint-preserving procedure, has been reported as a viable surgical option for younger patients with isolated medial compartment arthritis.^{1,3-9} It has been reported that young active patients with isolated medial compartment disease and varus knee alignment have the highest likelihood of a good outcome with an osteotomy,^{1,3,5,9,10} which can delay, or potentially avoid, the need for a total knee arthroplasty.¹¹⁻¹³

Both lateral closing wedge and medial opening wedge proximal tibial osteotomies have been described.^{4,6,10,14-16} With the introduction of improved stabilizing implants and an array of allograft bone and bone graft substitute options, medial opening wedge osteotomies are now often the technique of choice.^{17,18} The opening wedge technique offers several potential advantages: avoidance of rare surgical complications related to fibular osteotomy and deep muscle dissection^{7,19,20}; the need for only 1 bone cut, which may result in increased precision of correction and an improved ability for biplanar corrections^{11,17,21}; and preservation of tibial bone stock for future total knee arthroplasty.^{10,22-24} Potential disadvantages to this technique compared with the closing wedge technique include delayed time to full weight bearing, higher risk of hardware failure, and delayed union or nonunion.^{2,5,7,11}

Although there have been many studies reporting on the results of closing wedge osteotomies,^{1,3,4,9,25,26} there are fewer studies on the outcomes of proximal tibial opening wedge osteotomies,^{11,21,22,27} all of which have a short follow-up period. The purposes of our study were (1) to conduct a prospective outcome analysis of proximal tibial opening wedge osteotomies performed in young and middle-aged patients (aged <55 years) for the treatment of symptomatic medial compartment osteoarthritis of the knee and (2) to quantify the landmarks of the tibial eminence in terms of a percentage from medial to lateral along the plateau for use in objective descriptions of lower extremity mechanical axis. Our hypothesis was that young and middle-aged adults with medial compartment arthritis and genu varus alignment treated with a proximal tibial opening wedge osteotomy would have a significant improvement in subjective and objective outcome scores.

METHODS

Patient Selection

Between May 2000 and July 2007, all patients who underwent a proximal tibial opening wedge osteotomy for medial compartment osteoarthritis and genu varus alignment were followed up prospectively. Institutional review board approval was obtained from the University of Minnesota (Minneapolis, MN), and all patients signed an informed consent form to participate in the study. All operative procedures were performed by the senior author (R.F.L.). The inclusion criteria for this study were skeletally mature patients with radiographically evident, symptomatic medial

compartment knee osteoarthritis associated with genu varus alignment. Genu varus was defined as a mechanical weight-bearing line intersecting the tibial plateau medial to the tip of the medial tibial eminence (Fig 1).^{28,29}

Before the surgery was deemed to be indicated, all patients were prescribed a 2-month trial using a medial compartment unloader knee brace to determine whether an osteotomy was likely to be successful in relieving their pain and associated symptoms. Patients were excluded from this study if they did not have pain relief with the unloader brace. Additional exclusion criteria included the following: combination of the osteotomy with knee procedures other than arthroscopy and treatment of meniscal lesions, osteotomy as the first stage of future ligamentous or meniscal transplant reconstruction, inability and/or refusal to cease the use of all tobacco products, inflammatory arthritis or osteonecrosis, corticosteroid use, and degenerative changes with a Kellgren-Lawrence grade³⁰ greater than 2 (presence of osteophytes and some joint space narrowing) in the lateral compartment of the knee.

Preoperative Evaluation

At the preoperative visit, patients completed a modified Cincinnati Knee Survey.³¹ The International Knee Documentation Committee objective knee examination form subscores for knee effusions and the single-leg hop were also recorded. Patient knee range of motion, for both the affected knee and the contralateral knee, was examined with a goniometer and recorded by the senior author. Patient body mass index (BMI) (in kilograms per square meter), age, and sex were recorded.

All patients were evaluated with anteroposterior (AP) and lateral knee radiographs, a 45° patellar axial radiographic view, and a long single-leg standing AP alignment radiograph. The mechanical axis was determined by calculating the weight-bearing mechanical axis by drawing a straight line from the center of the femoral head to the center of the talar dome. The intersection of this line along the width of the tibial plateau was measured and reported as a percentage, where 0% was defined as the medial edge of the tibial plateau and 100% was defined as the lateral edge of the tibial plateau.^{28,29,32} It has been our practice to record the patients' weight-bearing line according to the percentage where the mechanical axis crosses the tibia to normalize the differences in patient height and sex.^{28,29}

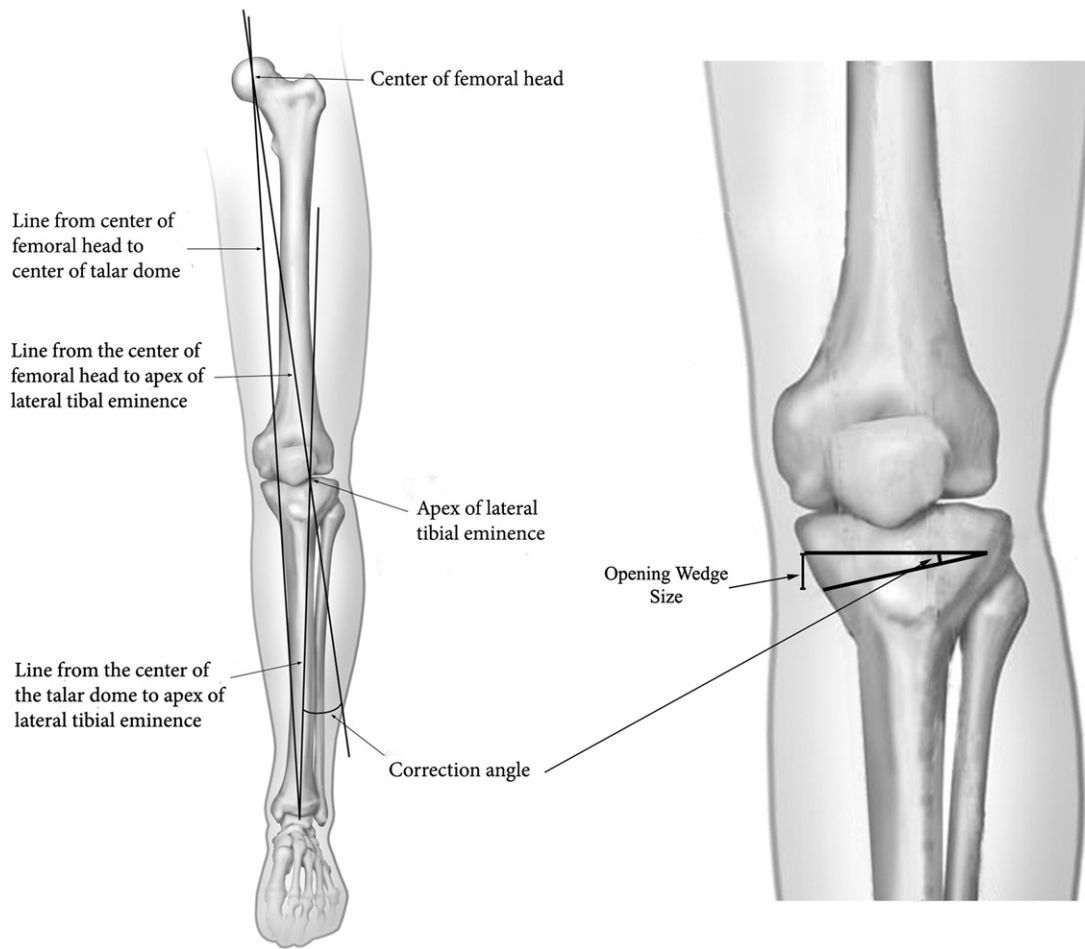


FIGURE 1. Mechanical axis weight-bearing line and desired osteotomy correction angle. A straight line is drawn from the center of the femoral head to the center of the talar dome to measure the mechanical axis. The desired correction angle is calculated from lines from the center of the hip and center of the talus through the apex of the lateral tibial eminence. This angle is transposed to the proximal tibia to calculate the desired opening wedge size in millimeters.

Preoperative planning was carefully performed with the goal to restore the mechanical axis through the tip of the lateral tibial eminence. This was accomplished by use of a method similar to that described by Dugdale et al.³² The desired angle of correction was determined by first drawing a line from the center of the femoral head through the apex of the lateral tibial eminence. Next, a line was drawn from the center of the talar dome through the same point on the tibia. The angle formed by the intersection of these 2 lines provided the necessary osteotomy correction angle (Fig 1). The appropriately sized opening wedge (in millimeters) was then calculated by transposing this angle at the location of the osteotomy cut at the proximal tibial physal scar (apex lateral) and measuring the height of the angle as it intersected the medial tibial (opening) border.

The Insall-Salvati index was calculated as a radiologic measurement for quantifying patellar height.³³ Posterior tibial slope was measured digitally according to the method described by Pietrini et al.³⁴

Operative Technique

After diagnostic knee arthroscopy when indicated, a 5-cm vertical skin incision was made over the antero-medial aspect of the tibia, midway between the tibial tubercle and the posterior border of the tibia and extending from 1 cm distal to the medial joint line to just distal to the tibial tubercle. The incision was performed directly down to bone. A subperiosteal dissection was performed anteriorly under the patellar tendon and posteriorly deep to the pes anserine tendons, superficial medial collateral ligament, and pop-

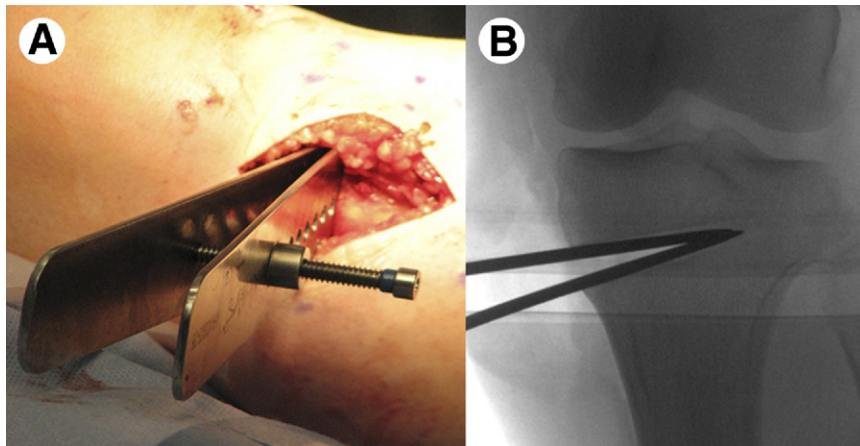


FIGURE 2. (A) Intraoperative photograph and (B) AP fluoroscopic view of knee-opening spreader device opening the osteotomy (left knee).

liteus musculature. Release of the more anterior fibers of the tibial attachment of the superficial medial collateral ligament was performed, allowing for palpation posteriorly along the planned location of the osteotomy. Two guide pins were then fluoroscopically drilled across the proximal tibia at the level of the physal scar and parallel to the joint line. An oscillating saw scored the medial cortex distal to the guide pins, and osteotomes were then used to complete the osteotomy anteriorly and posteriorly. One centimeter of the lateral cortex was left intact on the lateral side.

A spreader device was used to slowly open the osteotomy (Fig 2) to the calculated correction. Slow opening (periodic rest after increments of opening) allowed for stress relaxation of the osteotomy site. A separate device was placed to keep the osteotomy open, which allowed for concurrent insertion of the osteotomy plate (standard Puddu plate; Arthrex, Naples, FL). We placed the plate as far posterior as possible to avoid increasing the tibial slope. We did not try to change the sagittal slope for any patients in this series. Two 6.5-mm nonlocking fully threaded cancellous screws were placed proximally, and two 4.5-mm nonlocking self-tapping screws were positioned distally for bicortical fixation. The osteotomy site was then filled with allograft bone graft (Osteform; Exactech, Gainesville, FL). The pes anserine tendons and sartorius fascia were closed as a deep layer over the plate. The skin was then closed with an absorbable monofilament suture.

Postoperative Care

Patients were instructed to be non-weight bearing for 8 weeks. The initial rehabilitation protocol consisted of isometric quadriceps sets, patellar mobiliza-

tion, and straight-leg raises in a knee immobilizer 4 times daily. Patients were encouraged to remove the immobilizer 4 times daily to work on knee motion, striving for a minimum range of 0° to 90° by the end of the first 2 weeks, and increasing to a full range of motion as tolerated.

Deep venous thrombosis prophylaxis included intermittent compression boots for mechanical prophylaxis and enteric-coated aspirin, 325 mg daily for 8 weeks, for chemoprophylaxis. In patients with a history of a deep venous thrombosis or coagulopathy, enoxaparin (Sanofi-Aventis, Bridgewater, NJ), 40 mg subcutaneously daily for 4 weeks, was used in place of aspirin.

Patients returned to our institution at routine intervals for evaluation of their clinical and radiographic progression with AP and lateral knee radiographs. Partial weight bearing (25% body weight), the use of a stationary bicycle, and leg presses at 25% body weight were started at 8 weeks postoperatively if the radiographs were interpreted to have evidence of healing at the lateral aspect of the osteotomy. Patients advanced weight bearing by 25% of their body weight per week starting at 8 weeks. At 3 months postoperatively, they were allowed to wean off of crutch use as tolerated if radiographic healing was present and they had no increased pain or effusions with weight-bearing activities.

Follow-up and Data Collection

Patients were evaluated again at 6 months postoperatively and yearly thereafter. Radiographs were obtained at each visit to evaluate alignment and the osteotomy site (Fig 3). Patient outcome score sheets



FIGURE 3. Postoperative radiographs depicting AP and lateral views of knee 2 years after correction with medial opening wedge osteotomy (right knee).

were provided to patients at check in and returned to the clinic staff before the patients visited with the surgeon. Any complications or adverse events were recorded. Failure of the operation was defined as occurring in patients who either required a revision of the osteotomy or went on to receive a total knee arthroplasty.

Mechanical Axis Weight-Bearing Line Landmarks

In an effort to correlate the mean mechanical axis weight-bearing line to known radiographic landmarks, a concurrent radiographic analysis was performed on 137 consecutive patients with AP intercondylar notch radiographs who were aged between 19 and 54 years. These patients were separate from the patients included in the osteotomy study. None of these patients had tibial osteophytes or more than mild joint-space narrowing, so no patients were excluded. This portion of the study was approved by the Institutional Review Board at Vail Valley Medical Center (Vail, CO). Measurements were collected with a picture archiving and communication system program (Office PACS; Stryker Imaging, Kalamazoo, MI). On the AP notch radiograph, a line was drawn from the proximal medial border of the medial tibial plateau to the proximal

lateral border of the lateral tibial plateau. This distance represented the width of the proximal tibia (line M1) (Fig 4). Next, a line was drawn perpendicular to M1 through the superior apex of the medial tibial eminence. A parallel line to M1 was drawn from the medial border of the medial tibial plateau to the perpendicular line, locating the medial tibial eminence (line M2) (Fig 4). Another perpendicular line to M1 was created to intersect the superior apex of the lateral tibial eminence. Again, a parallel line to M1 was drawn from the medial border of the medial tibial plateau to the second perpendicular line, locating the lateral tibial eminence (line M3) (Fig 4). The ratio of the distance of M2 to M1 provided the percentage of the medial tibial eminence location in relation to proximal tibial width, just as the ratio of the distance of M3 to M1 provided the percentage of the lateral tibial eminence location in relation to the proximal tibial width.

Four weeks later, the measurements were repeated by the same observer (K.S.J.), and the intraclass correlation coefficient (ICC) was calculated using a 95% confidence interval (CI). A score less than 0.4 indicates poor reliability; a score between 0.4 and 0.74 indicates fair or moderate reliability; and a score of 0.75 or higher indicates excellent reliability.³⁵

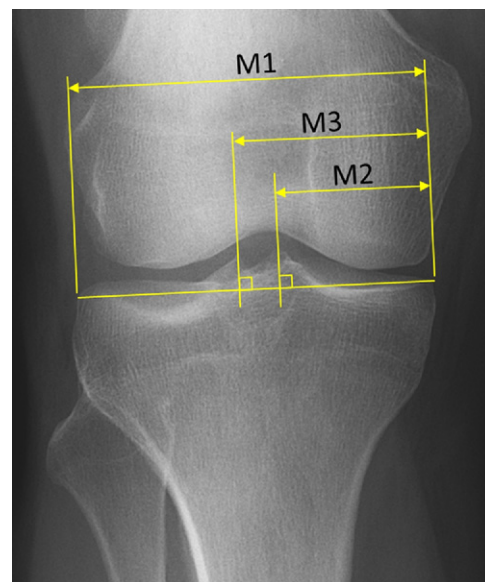


FIGURE 4. Notch radiograph (right knee) showing calculation of mean location of medial and lateral tibial eminences along width of proximal tibia. (M1, width of proximal tibia between far medial and lateral edges; line M2, width from edge of medial tibial plateau to medial tibial eminence, parallel to line M1; line M3, width from edge of medial tibial plateau to lateral tibial eminence, parallel to line M1.)

Statistical Analysis

Paired *t* tests and unpaired *t* tests were used to compare the differences in outcome scores when 2 groups were present. A 1-way analysis of variance test was used when a comparison was made among 3 groups. Statistical significance was defined as $P < .05$.

RESULTS

Demographics

Of the 59 patients who underwent a proximal tibial opening wedge osteotomy for treatment of symptomatic medial compartment arthritis, 12 were lost to follow-up and were excluded from analysis. Of these 12 patients, 1 died 18 months after the osteotomy from disease unrelated to the surgery, 2 moved out of the area, and the remaining 9 were unable to be located. Thus 47 patients were available for this study, and their demographic information is included in Table 1.

Outcome Scores

The mean preoperative modified Cincinnati Knee Score was 42.9 (range, 8 to 63). At the time of last follow-up, the mean score significantly improved to 65.1 (range, 10 to 100) ($P < .0001$). Preoperatively, the mean symptom subscore was 18.5 (range, 0 to 46) and the mean function subscore was 24.2 (range, 8 to 46). Postoperatively, the mean symptom subscore significantly improved to 31.3 (range, 0 to 50) ($P < .0001$) and the mean function subscore improved to 34.2 (range, 10 to 50) ($P < .001$) (Fig 5). Modified Cincinnati Knee Score data at 6 months, 1 year, and 2 years, as well as at the time of last follow-up, are presented in Fig 6. There was a significant difference

noted between preoperative scores and postoperative scores at 6 months (52.0) ($P < .02$), 1 year (61.6) ($P < .01$), and 2 years (64.2) ($P < .001$), as well as at the time of last follow-up (65.1) ($P < .0001$).

The preoperative and postoperative International Knee Documentation Committee objective knee scores for effusions and the single-leg hop are shown in Table 2. Significant differences between the preoperative and postoperative subscores were seen for both effusions and the single-leg hop ($P < .0001$).

Data were also analyzed based on BMI categories,³⁶ weight-bearing line correction groups, age, sex, and opening wedge size (Table 3). There was no significant difference found between these groups with regard to postoperative scores or improvement in scores.

Range of Motion

The mean preoperative range of motion was 0° of extension (range, -5° to 7°) to 133° of flexion (range, 120° to 140°), with mean contralateral knee motion values of -2° of extension (range, -10° to 15°) to 135° of flexion (range, 110° to 140°). Postoperatively, there was no significant difference noted in motion of the operative knee, with a mean range of motion of 1° of extension (range, -5° to 7°) to 133° of flexion (range, 120° to 140°).

Radiographic Results

Union: There was 1 case of delayed union and 1 case of nonunion. These are described in further detail in the "Complications" section below.

AP Mechanical Axis Alignment: Radiographic measurements of mechanical axis anatomic landmarks showed that the apex of the medial tibial eminence was found to average 41% of the distance along the proximal tibia. The apex of the lateral tibial eminence averaged 56% of the width of the proximal tibia (Fig 7). The ICC for the measurement of the medial tibial eminence was 0.88 (95% confidence interval [CI], 0.85-0.91), whereas it was 0.91 (95% CI, 0.88-0.93) for measurement of the lateral tibial eminence, indicating excellent reliability.

Preoperatively, the mean weight-bearing mechanical axis line passed through the tibial plateau at 23% (range, 2% to 37%) of the distance along the proximal tibia. After the osteotomy, there was a significant increase in the mean corrected mechanical weight-bearing axis to 54% (range, 33% to 67%) ($P < .0001$).

Patellar Height: By use of the Insall-Salvati index, the mean patellar height significantly decreased from 1.03 (range, 0.71 to 1.34) preoperatively to 0.95 (range, 0.58 to 1.39) postoperatively ($P < .01$). Post-

TABLE 1. Demographic Data of Study Patients

	Data
Total No. of osteotomies	47
No. of male patients	32
No. of female patients	15
No. of patients with previous tobacco use	5
Mean postoperative follow-up (yr)	3.6 (range, 2.0-8.9)
Mean age (yr)	40.5 (range, 21-53)
Mean BMI (kg/m ²)	28.3 (range, 19.2-47.4)
Mean plate size (mm)	10 (range, 5-15)
No. of patients with intact ACL	47/47
No. of patients with concurrent partial meniscectomy	6/47

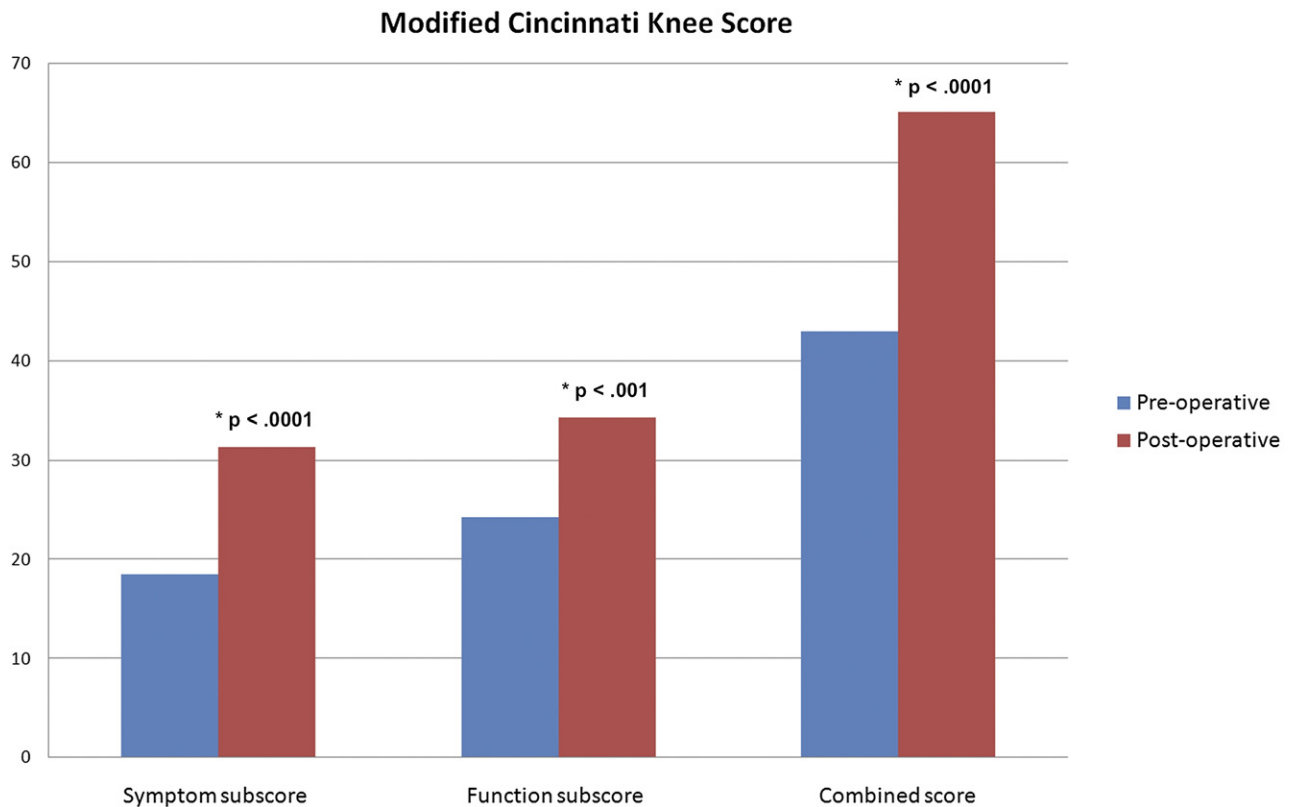


FIGURE 5. Modified Cincinnati Knee Scores broken down by symptom subscore, function subscore, and combined score. The data represent preoperative scores and scores at final follow-up. The asterisks indicate statistical significance compared with preoperative scores.

operatively, 8 patients (including 4 who had patella baja preoperatively) had documented patella baja with an Insall-Salvati index of less than 0.8.

Tibial Slope: The mean preoperative posterior tibial slope was 9.4° (range, 3° to 16°). Posterior tibial slope significantly increased to 11.7° (range, 2° to 22°) postoperatively ($P < .01$).

Complications

There were no neurovascular injuries, deep infections, deep venous thromboses, hardware failures, or cases of postoperative arthrofibrosis. The most common complication was hardware irritation treated with hardware removal, which occurred in 9 patients. There was 1 case of cellulitis that resolved with oral antibiotic treatment. There was 1 intraoperative fracture of the lateral tibial cortex. This was stabilized laterally with 2 medium bone staples, and the osteotomy healed by 3 months. Another patient sustained a nondisplaced fracture of the lateral cortex after a fall 1 month postoperatively. This patient

had delayed healing of the osteotomy, but after use of a bone stimulator, good callous formation developed 5 months postoperatively. A nonunion occurred in a patient with a history of tobacco use who had quit just before the operation and resumed smoking postoperatively. Management included hardware removal and a distraction osteogenesis with an external fixator, with healing at 10 months. There were 2 patients who underwent total knee arthroplasty (at 5.8 and 6.6 years postoperatively).

DISCUSSION

In our study, we found that properly selected patients with symptomatic medial compartment osteoarthritis and genu varus alignment had significantly improved subjective and objective outcome scores when treated with a proximal tibial opening wedge osteotomy. The survival rate of the osteotomy in our patient cohort was 94% (44 of 47) at a mean follow-up of 3.6 years. Thus we recommend that this procedure be con-

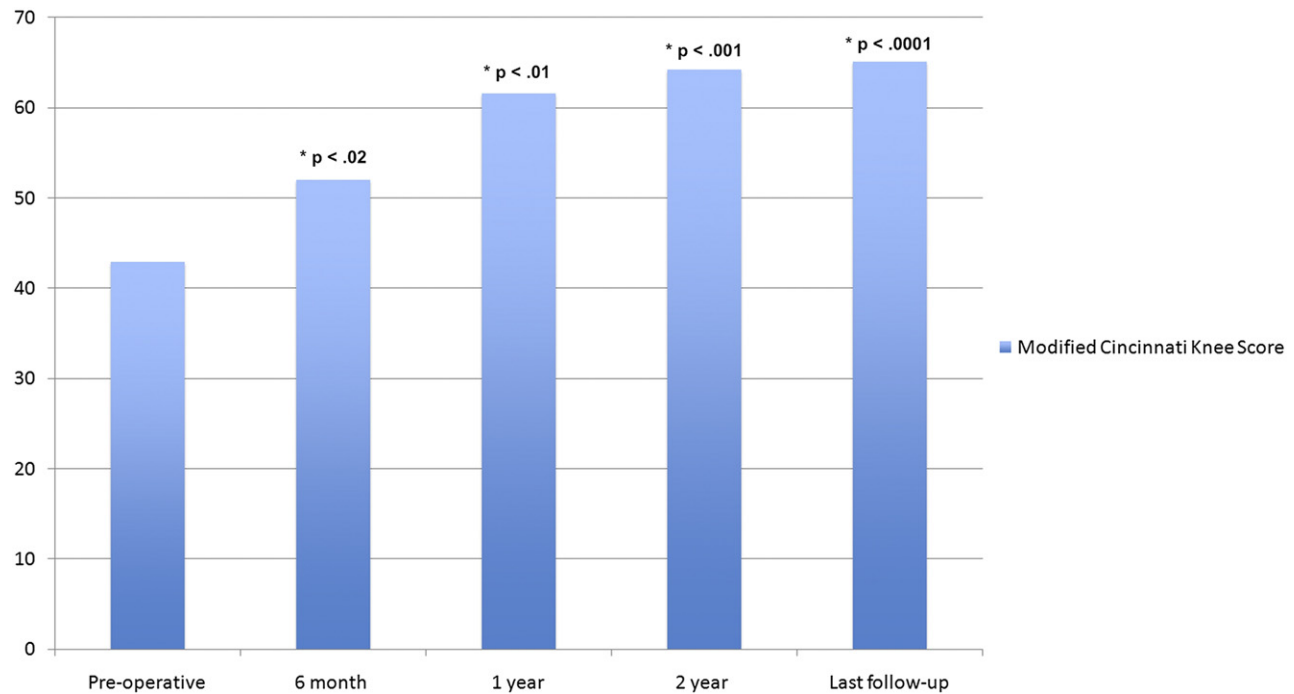


FIGURE 6. Modified Cincinnati Knee Scores before intervention; at 6 months, 1 year, and 2 years postoperatively; and at the time of last follow-up. The asterisks indicate statistical significance compared with preoperative scores.

sidered as an alternative to arthroplasty for younger and middle-aged patients with isolated medial compartment disease.

Our study found that correction of joint alignment to near the lateral tibial eminence resulted in a significant improvement in patient outcomes. Achieving and maintaining adequate correction of coronal-plane alignment has been reported to be an important determinant of good patient outcomes for proximal tibial osteotomies in most^{1,4,5,8,37} but not all studies.²⁵ On the basis of a long-term follow-up of 87 patients, Coventry et al.⁴ recommended overcorrection of

alignment to 8° to 10° of anatomic valgus angulation. Hernigou et al.⁵ found that 20 of the 28 knees that had been corrected to a mechanical axis of 3° to 6° of valgus had good clinical results. Insall et al.³⁷ initially reported better 5-year follow-up results in patients who underwent correction to an anatomic axis of 10° of valgus angulation (equivalent to 4° to 8° of mechanical axis alignment), but in a 10-year follow-up study on the same group of patients, they noted that the results of all osteotomies deteriorated significantly with time and that postoperative anatomic axis was not nearly as important.²⁵ These studies had signifi-

TABLE 2. *International Knee Documentation Committee Objective Subscore Evaluations for Effusions and Single-Leg Hop for Patients Undergoing Proximal Tibial Opening-Wedge Osteotomy*

	Effusions		Single-Leg Hop	
	Preoperative	Postoperative	Preoperative	Postoperative
Grade A (normal)	11	46	0	7
Grade B (near normal)	37	1	2	27
Grade C (abnormal)	10	0	30	13
Grade D (severely abnormal)	0	0	26	0

NOTE. Significant differences between the preoperative and postoperative subscores were seen for both effusions and the single-leg hop ($P < .0001$).

TABLE 3. Subgroup Analysis of Modified Cincinnati Knee Scores

	n	Modified Cincinnati Knee Score	
		Preoperative	Postoperative
BMI			
Normal (18.5-24.9 kg/m ²)	9	45.7	74.3
Overweight (25.0-29.9 kg/m ²)	27	46.3	65.7
Obese (≥ 30 kg/m ²)	11	35.6	57.4
Mechanical axis			
Group 1 (<51%)	15	48.0	68.7
Group 2 (51%-61%)	28	42.2	64.7
Group 3 (>61%)	4	28	54.3
Age			
<40 yr	22	44.2	66.3
40-53 yr	25	39.0	63.5
Sex			
Male	32	47.2	69.3
Female	15	29.6	56.4
Wedge size			
10-15 mm	26	44.0	69.0
5-9 mm	21	37.6	58.4

NOTE. There was no significant difference found between the groups with regard to postoperative scores or improvement in scores ($P > .05$).

cant variability in the patient demographic characteristics, as well as preoperative alignment and arthritis characteristics; however, the concept of the mechanical axis correction remains valid.

It has been reported that when the weight-bearing mechanical axis is 0°, the anatomic axis in patients averages 6°.38 With the general postoperative guidelines for post-osteotomy alignment striving for an anatomic axis of between 7° and 10°, it thus appears that the main goal has been to shift the mechanical axis to neutral or slight valgus alignment. On the basis of our synthesis of the available literature at the initiation of this prospective study in 2000, as well as our experience at our institution, we chose the apex of the lateral tibial eminence (56%) as our goal for correction for the mechanical axis because it represents an anatomic axis of approximately 10°. This provides the benefit of mechanical realignment without overloading the lateral compartment or creating a cosmetically unappealing valgus deformity.2,8,9,39 On average, the patients in our series had alignment maintained at the 54% point at a mean of 3.6 years' follow-up, and this translated to substantial improvement in outcome scores.

There were only 3 failures (94% survival), with no patients awaiting a revision or knee arthroplasty, at a

mean of 3.6 years' follow-up. This is consistent with results reported for studies for both the medial opening and lateral closing wedge proximal tibial osteotomy techniques. Nagel et al.² reported a rate of revision to total knee arthroplasty of 17.6% for 34 patients followed up for a minimum of 2 years. In an initial study of opening wedge osteotomies without hardware fixation conducted by Hernigou et al.,⁵ failure occurred in 17 of 93 patients (18%) at 5 to 10 years postoperatively.

Although we found no significant differences in patient outcomes based on BMI, our series was underpowered to detect such differences, and other authors have reported conflicting differences. Matthews et al.⁴⁰ reported a relation between obesity and early failure of proximal tibial osteotomies, and obesity has been reported by some authors to be a relative contraindication to treatment with an osteotomy.^{4,17,25,41} In contrast, Jakob and Murphy⁴² reported improved outcomes in heavier patients.

In this study we found a small but statistically significant increase in postoperative tibial slope. Although we recognize and often use the technique of altering the sagittal plane to manage instability or other conditions, this was not performed in this cohort. We attempted only to correct coronal-plane alignment to offload the arthritic medial compartment. Our results indicate that we were successful in accomplishing this, with only a 2.3° increase in the sagittal-plane tibial slope. Whether this increase in slope is clinically

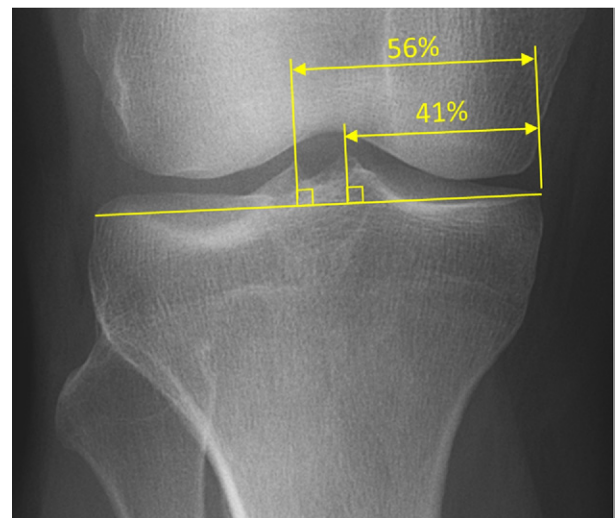


FIGURE 7. Notch-view radiograph (right knee) showing percentage width of medial and lateral tibial eminences as measured from medial border of medial tibial plateau among 137 consecutive patients (274 knees).

important has not been determined, but it is likely that it is small enough that it will not affect patient function or joint loading substantially. We found no measurable decrease in knee extension, which should occur with clinically significant increases in posterior tibial slope. Other studies have also reported that the opening wedge osteotomy procedure for the treatment of osteoarthritis increases the posterior tibial slope, by a mean of 1.0° to 5.5° , depending on the location and size of the osteotomy plate.^{7,19,31,43-45} It is an essential component of preoperative planning to determine whether changes in sagittal-plane tibial slope are desired because of concurrent cruciate ligament tears or, more relevant to this patient population, the presence of more localized areas of arthritis, as well as to be cognizant of trying to avoid increases in sagittal-plane loads on an arthritic area of the knee.

In this study we found that patellar height decreased postoperatively for the majority of patients (74%). This was similar to the results reported in studies on both closing and opening wedge osteotomies that examined patellar height.^{31,45-47} It has been suggested that changes in postoperative patellar height may be related to scarring of the patellar tendon postoperatively, arthrofibrosis, and the need for immobilization.^{24,46,47} Although we did not believe that this patella baja was clinically significant in our patient population, it is very important to assess for changes in patellar height because it could affect surgical exposure during the future arthroplasty.⁴⁸

Finally, we also found that the mean location of the apex of the medial tibial eminence was at 41% of the width of the tibia when measured from medial (0%) to lateral (100%). This is an important reference number because conventional teaching is that genu varus alignment is believed to be present when the mechanical axis weight-bearing line falls medial to the apex of the medial tibial eminence.

Strengths of this study were that the same clinical diagnosis was present and the same surgical technique and fixation plate were used in all patients. Furthermore, our data were prospectively collected in a consecutive series, and we obtained a midterm length of follow-up.

We recognize that there are limitations to this study. Even though this was a prospective study, only 1 surgeon was included and only 1 technique was used, and there is no comparative group for analysis. There were 12 patients who were lost to follow-up, representing approximately 20% of our original group. We also recognize that although all patients in this series had a minimum of 2 years' follow-up, this is a rela-

tively short duration and further long-term follow-up is necessary to determine the overall ability of the surgery to delay or avoid total knee arthroplasty.

CONCLUSIONS

Performing proximal tibial opening wedge osteotomies to treat symptomatic medial compartment osteoarthritis in carefully selected patients leads to a significant improvement in subjective and objective clinical outcome scores with correction of malalignment at a mean of 3.6 years postoperatively.

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